

TELESCIENCE SYSTEM DEFINITION

FINAL REPORT

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by

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Abstract

Tele-operations of a unique scientific apparatus were defined and undertaken such that a scientist could perform thermal analysis in a high temperature furnace from a remote location. An ellipsoidal furnace was adapted to remote operation (quasi-robotic and not automatic) to provide a user confident control over the experiment conditions and obtain complete data at the remote site for immediate evaluation. Corrective actions or adjustments could be established in real time and the experiments repeated indefinitely. Data storage is monitored and maintained by the remote user. Remote access and replay of data is supported. Certain forms of equipment failure are indicated to the remote user so that decisions can be made for further operations, such as reduced capabilities. Inappropriate experiment conditions are identified and the user informed. The significant hurdle of having the experiment operate at rates that differ from real-time was satisfied through rigorous programming of the Supervisory Program.

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I. Introduction:

The purpose of this work was to perform systems engineering and software studies in establishing requirements for ground/mission operations for the Shuttle and Space Station. This includes studies for telescience systems definitions, test bed and workstation design and layout, and system software and hardware analysis.

Telescience operations were evaluated and refined to improve control over experiment exercises. The issues with Telescience deal mostly with the ability to perform experiments from a remote location as if the investigator were physically present at the experiment apparatus.

Significant issues in Telescience include:

1. Data acquisition methods
2. Data presentation methods
3. Data storage and post acquisition processing
4. Data transmission methods
5. Degree of remote control over various functions at the experiment, e.g.. can one exchange samples?
6. Rate of transmission limits to data quality
7. Rate of transmission limits to data quantity
8. 'Intelligence' of the Supervisory Program to
 - a) properly perform the investigator's directions,
 - b) monitor the experiment for malfunctions,
 - c) inform the remote workstation of problems,
 - d) inform the investigator of valid conditions,
 - e) warn the investigator that the desired experimental parameters were out of bounds
 - f) return control to the remote station after a catastrophic malfunction at either end.

Most the issues above have been implemented in one form or another and to a degree permitted by the time allowed. Several of the issues would be worthwhile to pursue; especially the use of Artificial Intelligence techniques in the Supervisory Program (of any such Telescience application).

The system consists of a workstation and test bed with a central computer for control of all function. The major emphasis entailed programming the control computer at the Testbed to

produce a management program to perform the experiments in a prescribed way according to the P.I.'s commands. This is the Telescience Supervisory Program in the Testbed System. It also handles the Telescience Control and Monitoring functions which are not specifically an experiment variable. Since this was experimental work, specifications were developed during the initial operation of the equipment which lead to progressive program modification and improvements. A sub-task was to refine the test bed capabilities to enhance the level of scientific data quality and meet the telescience requirements to a similar degree.

A Thermal Analysis System already existed at MSFC and was one subsystem for this project. Automation of this apparatus, including the ability to control the experiment remotely for Telescience purposes was the ultimate goal. The second major sub-system was the Keithly 500 Data Acquisition and Control System which interfaced the Thermal Sub-system to the Computer Testbed Subsystem. The integrated software control program was developed to collect data at the test bed and communicate with the remote workstation which was itself a computer and communications system. Control signals transmitted from the remote workstation over telephone lines controlled the experiment. System tests and verification were performed. This report outlines the results from this contracted effort.

The function of the thermal analysis apparatus is to heat and then cool a specimen suspended at the end of a type S thermocouple. The action of heating to temperatures up to 1800 degrees C is accomplished by the ellipsoidal furnace powered by a halogen lamp. The emitted energy of the lamp is focused onto the specimen and concentrated such that the specimen is heated by the radiation. The thermocouple is intimately mated to the specimen such that the thermal response of the system is extremely rapid. As a consequence, high data rates are required during data acquisition. The heating lamp must be gas cooled to protect it and the specimen can be gas cooled by a separate gas nozzle. All this activity occurs within the furnace and in air. Due to the high temperatures, ceramic oxide materials which may form amorphous structures are the prime candidate specimens. Oxidation is therefore not a problem, although volatilization may be. Thermal cycling of the specimen through various rates of cooling while monitoring the thermal response yields nucleation data for the prospective material. High rates of cooling reduce the probability that nucleation of a crystal occurs, and a glass forms instead. The rates are strongly dependent on the material being tested.

II. Development Stages:

First Stage:

In preparation for the integration, the Keithly 500 Data Acquisition System was installed in the computer bus, the controlling software installed in the computer and the series of programs assembled and run to make the various components of the system work together. A part of this effort was to lay out the apparatus and instrumentation in an organized fashion to permit efficient working conditions during these early stages. The layout of the Testbed is shown in Figure 1.

All components of the Keithly system were checked out and configured for operation. Some programs were written to get familiarized with the hardware. At the same time, an evaluation of the capabilities of this system were being made.

Modification of some circuit boards and the safe mounting of the high voltage components was done as a first stage for the control of the ellipsoidal furnace which is a part of the Thermal Analysis Subsystem. It is the control over this device that is most scientifically critical to this project. The second factor is accurate and rapid monitoring of temperature in the specimen both for scientific data collection and for the control over the experiment in real time during tele-operations.

Second Stage:

A control box to contain the power switching relays was put together and integrated to the Testbed System. A portion of the computer computer control wiring connected to this Signal Control Center. Main power control was provided by taking a rack mount relay control with safety switch and rewiring it for the this application. This became the Power Control Center and was connected to the Signal Control Center. At this stage the computer has control over the main power into the furnace and into the motor speed control.

Third Stage:

A program was written to control the experiment, display and save the data obtained from the furnace. This became the first version of the Telescience Supervisory Program. The temperature limit is presently the software limit of the Keithly DAC 500 which is 1450 deg. C.

Fourth Stage:

Fine tuning and operation of the telescience system was undertaken. The apparatus could be used in the local mode for data collection and performing experiments. Experiments to quantify performance factors were devised and implemented. The fine tuning referred to the verification of the reliability of the timing for the measurements and where possible, that the results met the manufacturer's specifications for the acquisition system. Considerable time was spent modifying the Telescience Supervisory Program in order to verify the performance. A commercial program (R2 from Crosstalk) was obtained to perform communications control between the Testbed and the remote Workstation. This program was selected because it provided real-time (with limitations) control over the Testbed computer from virtually any other personal computer that could communicate over the phone lines and supported the software. It permitted a remote user to receive the text, graphics and data from the Testbed as if they were physically present at the Testbed location.

Fifth Stage:

Two subsystems were added to the Telescience system. Both subsystem additions increased the cooling rate capability for the system. The first was the addition of a control solenoid to allow gas quenching (with air or bottled gas) of the heated specimen. Another modification was the addition of a thermocouple support. A special relay was also added which permitted control over the conduction of heating power to the furnace. Major revisions and improvements to the plumbing and wiring were also made. Test runs showed maximum cooling rates of over 3000 deg/sec. after the modifications.

Sixth Stage:

The software was enhanced to provide graphic playback of the results via remote operation. This way, a review of the data is possible and a means of recovery provided should a failure occur. Prior to this, if a failure occurred after the data was collected and displayed, it would be lost. Monitoring of the heat-up cycle and routines to reduce errors were also added. This serves to inform the investigator of a problem during the run and prevents irreparable damage to the equipment. Discussions with KEITHLY has resulted in their sending a software update to the SOFT500 System. There was no observed incompatibility between the new and old software and modifications to the Supervisory Program were not needed. For the most part, the software improvements did not significantly alter the performance of the Testbed.

Seventh Stage:

The Supervisory Program was rewritten to enhance the telescience tasks and serve as a remote control program. Testing was done by remote access via Dr. Ethridge's IBM AT computer and the PABX system at MSFC. Communications could proceed at up to 9600 baud. Due to the interrupt requirements of the Supervisory Program and the communications software which ran concurrently, acquisition speed was compromised. Transmission of Graphics images was very successful but annoyingly slowed at the baud rates allowed.

III. The Supervisory Program:

Programming the Keithly 500 Data Acquisition System was performed through the BASIC Programming Language. As a consequence, the Supervisory Program for the Testbed was completely written in this language. A listing of one of the last versions of this program is presented in the Appendix.

It is important to note that a more sophisticated or faster language was not required to monitor the Keithly System. A special system was provided by Keithly to permit control of their devices using special commands which were powerful machine level routines themselves. Microsecond timing control over the multiple, simultaneous functions was considerably simplified.

It is the BASIC Supervisory Program which provides the Telescience control and intelligence and is the user interface.

At the Testbed, the sequence of (computer) programs is as follows:

1. At power-up, the computer accesses its own ROM BIOS (boot program) to find the next program to run...
2. on the hard disk are the various pieces of information required to bring up the Disk Operating System...
3. after DOS, an Autoexec.bat program initiates the Keithly Soft 500 program (which allows BASIC to gain control over the Data Acquisition System). Then
4. the Remote2 Host communications program is then invoked to permit remote operation and communications via the communications (COM) port in the computer of the Testbed. At this port is found the hardware to connect the computer to the MSFC PABX (phone) communications system. Whether the COM-port is connected to the PABX and the phone lines, or a modem and the phone lines, or a long wire to the workstation, or to a satellite transponder, etc., remote communications at any distance would be possible.

At the remote Workstation:

1. With communications established from a remote workstation using R2Call software, the GWBasic interpreter program in the Testbed is invoked such that subsequent operations are performed in this environment. (R2Call is the mate program to R2Host which is also from Crosstalk.)

2. The Telescience Supervisory Program (stored at the Testbed) is loaded from the GWBasic interpreter and then the program is RUN in the Testbed computer. At any time, the always-ready R2Call communications menu at the Workstation can be invoked to perform alternate functions in the Testbed outside of the Supervisory Program.

The user communicates with the Testbed over the phone lines (PABX) using Remote2 Call communications software, a companion to the Host program. This action is performed at the Workstation. Any IBM-compatible computer connected to a phone line or PABX would suffice as a Workstation. Once connected, the user then runs BASIC and then loads and runs the Supervisory Program. At this point, the user interfaces solely through the Supervisory Program and performs experiments and collects data. If necessary, the Supervisory Program could be presented to the user and minimizes steps as well as offer transparency to the user. For this developmental level, such a refinement was not felt to be of significant value.

Sample 'screens' the user would see at the Workstation are shown in Figures 2-4 as a sequence in the order of occurrence.

Once the experiment conditions have been established, the experiment or experiments are run. A comprehensive experiment includes data collection and display during heating and cooling the specimen. Usually, critical thermal data is obtained on cooling alone, but a determination of crystallinity can be made from the specimen thermal response on heating to above the melting point. This determination can be made for the specimen condition established just prior to the heating cycle, such as a previous experiment. Scientific evaluation and hypothesis testing can thereby be performed while still 'on-line'. The next experiment can be configured according to the user's immediate plan of action even though it may be amended at any time.

A real time system monitor function is provided by the Supervisory Program where specimen temperature and the stage of the experiment is presented to the user at the Workstation. This is needed because once the experiment run is initiated, it cannot be stopped, even if a communications failure breaks the link between the Workstation and the Testbed. Except for a power failure at the Testbed, once the experiment is under way, the user is assured of having data for that run.

Once data are collected, the arrays are saved in the Microsoft Lotus 123 spreadsheet file format. Time and temperature is recorded in the file while data is being collected and a plot of the system temperature is shown in real time on the user's screen at the Workstation (and at the Testbed). The sampling interval is set by the user but must match the available range for the system. A series of experiments can automatically

be pre-set and unique sequentially labeled files created for each. Data reduction and manipulation can be performed within Lotus 123 after the data is collected and not necessarily in a telescience environment.

IV. System performance:

Most significant performance characteristics relate to the instrumentation control range. Maximum temperatures, maximum and minimum rates of cooling, reproducibility and accuracy are the parameters that interest the user most. The user sets temperatures that act as setpoints or bounds. Specimen mass, thermocouple mass, motor speed for heat-up / cool-down and gas flow rate together define the maximum cooling rates. These conditions are not controlled by the user at the remote workstation. As a result, pre-set cooling rates cannot be used. Instead, the user adjusts the conditions which relate to cooling rate to obtain the response desired. Secondly, required cooling rates can never be predicted. These are the reasons only an interactive system can be used, not a preprogrammed robot. Selection of whether the furnace is turned off, or the power ramped down or gas quenching applied, or combinations of these are at the disposal of the user. Ramp rate for heat-up and cool-down can be added to the Supervisory Program once the hardware would be installed, ie. there is no reason this could not be done. Insufficient time was available for this refinement.

Cooling rate is the most important single parameter and the apparatus was refined to achieve extremely high rates of cooling - as high as 4400 degrees C per second. This is achieved by turning off the power to the heating lamp and gas quenching at the same time. Such high rates of cooling are needed to prevent undesirable nucleation of crystals in the specimen.

One single run through the experiment with one specimen provides very little information. By repeating the cycle of heating and cooling many times and recording all the data, a scatter plot of the nucleation temperature against cooling rate can be assembled. This plot, consisting of perhaps 50 or more points is the highly desirable result. Glass formation characteristics can then be obtained from application of the appropriate model. The user can cycle the system as often as desired, limited only by the storage space on the computer hard disk for the data. The Supervisory Program maintains the indexing of the files generated from each run. Failure in the system could cause the loss of, at most, only one run of data.

The user has control over the resolution of the plot of temperature against time during the experiment. High resolution, in monochrome of 640 x 320 points is possible for the best plot quality and low resolution, colored plots of 320 x 280 points per

screen are available for rapid evaluation. The low resolution plot also permits data viewing from a remote workstation with less capability than the one used here. Other than this limitation, any IBM - style desk top computer can be used as a Workstation.

Computer speed and communications speed are not an issue since the critical timing functions are maintained by the Keithly 500. In fact, when communications become poor (noisy) or slow, the highest rates of data acquisition are still possible. Individual runs may take several minutes (as many as 20 minutes have been seen for one) under these circumstances. The R2 programs maintain data integrity despite the communications problems. The speed of communications have been established at rates of 9600, 2400 and 1200 Baud. Errors during communications caused by the PABX system at times significantly reduced response times below that expected by the Baud rate used. Slower response is merely an inconvenience.

Temperatures are measured from standard Type S thermocouples. The Keithly 500 provides room temperature compensation and conversion to Celsius degrees from the microvolt signals. The conversion is so rapid that the final temperatures are stored (the reference and the measured) in degrees rather than microvolts. Should higher speed be desired (less time between readings), storage followed by conversion could be implemented. The shortest reliable interval between readings has been found to be 8 milliseconds. Each reading represents a reference temperature and a measurement of specimen temperature linked to a reference. Temperature accuracy after conversion was determined to be plus or minus 0.5 degrees C.

Figures 5 and 6 are high quality plots of the data collected from typical runs after analysis within the spreadsheet software subsequent to data collection. Raw data can be plotted, Figure 5, while in Figure 6, the derivatives and therefore the cooling rates are shown. The high rates of data acquisition give excellent temporal resolution and the 12-bit A to D conversion resolution displays excellent thermal resolution and accuracy.

V. Conclusion

A unique Telescience Testbed was assembled and evaluated. Telescience functions were performed remotely from a Workstation which permitted the user to perform several experiments at the Thermal Analysis Telescience Testbed.

VI. Appendix

Listing of Telescience Supervisory program in GWBasic.

VII. Figures

```

1 GOTO 10
2
3     CALL ANREAD'("temp",VA,12)
4     LOCATE 20,20:PRINT "Temperature = ":LOCATE 20,40:PRINT VA;" Degrees C ";
5     RETURN
10
100
110
120
130
140
150
160
170 DEFDBL T
180 DIM E1(1008),E2(1008)
190 CALL INIT
200 SCREEN 2:SCREEN 0:COLOR 20,,3
210 LOCATE 1,20:PRINT "          POWER TO EXPERIMENT TURNED ON";
220 REM 2 IS GEEN, 3 IS BLUE, 4 IS RED ADD 16 TO FLASH IN COLOR
230 COLOR 3,,3
235 STATUS%=0
240 VA=0:VB=0:SK=0:REM va used for analog voltage, sk to skip anin
250 LOCATE 3,20:PRINT "MSFC Telescience Rapid Thermal Analysis Test Bed"
260 LOCATE 4,20:PRINT "SSL-ES74 Testbed Laboratory Bldg 4481 Rm. 405C"
280 CALL DIGWRITE'("dc7",1.0)
290 CALL IONAME'("COLD",6,32,14)
300 CALL IONAME'("temp",6,0,14)
310 GOSUB 2
320 COLOR 3,,3:REM COLOR 4,,3 is blue background red letters
325 LOCATE 6,20:INPUT "Use All Defaults for Experiment? (y/n)      ";DV$
326 IF DV$="y" THEN GOTO 330
330 LOCATE 6,20:INPUT "Input Warmup Time =                      ";WT
340 IF WT<1 OR WT>500 THEN WT=5
350 LOCATE 7,20:PRINT "WAITING                                  "
390 FOR I=1 TO WT:LOCATE 7,63:PRINT I;;GOSUB 2:NEXT I
400 LOCATE 8,20:INPUT "How many Experiment Runs?                [1]  ";NR
410 IF NR<1 OR NR>10 THEN NR=1
415 RN=1
420 LOCATE 9,20:INPUT "What is MOTOR SPEED set to =          [3]  ";SP
430 IF SP<.5 OR SP>8 THEN SP=3
440 LOCATE 10,20:INPUT "Turn on GAS quench? (y or n)          [Y]  ";Q$
450 IF Q$="y" OR Q$="n" THEN 460 ELSE Q$="y"
460 LOCATE 11,20:INPUT "Furnace OFF for quench? (y or n)       [Y]  ";F$
470 IF F$="y" OR F$="n" THEN 480 ELSE F$="y"
480 LOCATE 12,20:INPUT "Maximum Soak Temperature =          [300] ";MT
490 IF MT<100 OR MT>1500 THEN MT=300
500 LOCATE 13,20:INPUT "Input Soak DURATION in seconds =      [1]  ";ST
510 IF ST<1 OR ST>15 THEN ST=1
520 LOCATE 14,20:INPUT "NUMBER of Readings (300 to 1000)      [300] ";ND!
530 IF ND!<300 OR ND!>1000 THEN ND!=300
540 LOCATE 15,20:INPUT "FILE NAME for data =                  [TCDATA] ";TD$
550 IF TD$=" " OR TD$="" THEN TD$="TCDATA"
560 LOCATE 16,20:INPUT "INTERVAL between readings =          [50ms] ";MS%
570 IF MS%<10 THEN MS%=50
590 LOCATE 17,20:INPUT "Save Heat Up Cycle? (y or n)          [Y]  ";H$
600 IF H$="y" OR H$="n" THEN 620 ELSE H$="y"
620 GOSUB 2
650 REM
672 CLS
675 CALL ANIN'("ahRAY%",nd!,"COLD,TEMP",1,1,"WGO","HECK")

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680 LOCATE 1,20:PRINT "Run Number ";RN;" of ";NR;" Runs.
685 CALL WARNOFF
690 LOCATE 2,20:PRINT "Motor and Solenoid ON for Heat Up Cycle"
700 GOSUB 2:'          MOTOR ON ACO FURN. SOLENOID ON DC6      HEATUP CYCLE
750 CALL DIGWRITE'("ac0",1.0)
760 GOSUB 2:'          SOLENOID AC3 ON NEXT
780 GOSUB 2
790 CALL INTON'(MS%,"MIL")
800 CALL GO
805 T1=TIMER
810 CALL DIGWRITE'("ac3",1.0)
820 CALL DIGWRITE'("dc6",1.0)
830 GOSUB 2:T2=TIMER:DT=T2-T1
840 IF DT>20 THEN GOSUB 1120:END
870 IF VA<MT THEN 830:REM DELAY FOR WARMUP CYCLE THEN CLUTCH AND MOTOR OFF
872 LOCATE 4,20 :PRINT "HEATUP Time":LOCATE 4,40:PRINT DT;" sec"
880 REM Motor and Clutch Solenoid Off
890 CALL DIGWRITE'("ac3",0.0)
900 CALL DIGWRITE'("ac0",0.0)
905 GOSUB 2
910 LOCATE 5,20:PRINT "SOAK Time":LOCATE 5,40:PRINT "= ";ST;" sec"
915 LOCATE 6,20:PRINT "SOAK Temp":LOCATE 6,40:PRINT "= ";MT;" C"
920 CALL ANIN'("ARRAY%",nd!,"COLD,TEMP",1,1,"WGO","CHECK")
930 FOR I=1 TO ST:GOSUB 2:NEXT I
940 LOCATE 7,20:PRINT "Start Quench"
941 GOSUB 2
945 T1=TIMER
955 CALL GO
960 CALL DIGWRITE'("dc6",0.0)
965 CALL DIGWRITE'("ac1",1.0)
970 CALL DIGWRITE'("ac4",1.0)
975 CALL DIGWRITE'("ac5",1.0)
980 CALL INTOFF
982 T2=TIMER
984 LOCATE 8,20:PRINT "QUENCH Time":LOCATE 8,40:PRINT T2-T1;" sec"
985 GOSUB 2
990 GOSUB 1620:REM TURN OFF MOTOR AND SOLENOID AFTER COOL DOWN
991 GOSUB 2
992 'GOSUB 1760:REM SAVE DATA TO DISK HERE
993 LOCATE 14,20:INPUT "DO you wish to REVIEW GRAPH y or n: ";Y$
994 IF Y$="y" OR Y$="Y" THEN GOSUB 2300
995 GOSUB 2
996 GOSUB 1965:REM Clear Arrays
1000 RN=RN+1:IF RN<NR THEN 650:'          TO RE-ENTRY POINT
1005 RN=RN+1:IF RN<NR THEN 650:REM      TO RE-ENTRY POINT
1010 '          ALL POWER OFF
1015 CALL DIGWRITE'("dc7",0.0)
1020 LOCATE 7,20:PRINT "POWER to ALL equipment turned OFF"
1030 IF DT>20 THEN CALL INIT
1050 SCREEN 0:LOCATE 9,20:PRINT"";NR;" Runs Completed"
1055 GOSUB 2
1060 STOP
1070 '*****END OF PROGRAM*****
1120 REM -----TURN OFF MOTOR AND SOLENOID-----
1130 IF DT>20 THEN SCREEN 0:CLS:COLOR 20,,4:LOCATE 12,25
1135 PRINT"THERE IS A PROBLEM ON HEAT UP!!";:COLOR 3,,3
1140 GOSUB 2
1150 CALL DIGWRITE'("ac1",0.0)
1160 CALL DIGWRITE'("ac5",0.0)
1170 CALL DIGWRITE'("ac4",0.0)

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1180 IF VA>50 THEN GOSUB 1620
1190 LOCATE 8,20:PRINT "MOTOR AND SOLENOID TURNED OFF TO COMPLETE CYCLE":RETURN
1200 REM----- ALL POWER OFF-----
1210 CALL DIGWRITE'("dc7",0.0)
1220 PRINT "POWER to ALL equipment is NOW turned OFF"
1230 IF DT>20 THEN CALL INIT
1240 RETURN
1611 '-----END HEAT UP ACQUISITION-----
1620 REM COOL DOWN AND OFF CYCLE FOR MOTOR AND FURNACE
1630 LOCATE 10,20:PRINT "Temperature must be less than 100C to continue."
1640 CALL DIGWRITE'("AC1",1.0)
1650 CALL DIGWRITE'("AC3",0.0)
1660 CALL DIGWRITE'("AC4",1.0)
1670 CALL DIGWRITE'("AC0",0.0)
1680 REM FURNACE SHOULD BE COOL NOW
1690 VA=0
1700 GOSUB 2
1710 IF VA>100 THEN 1620
1720 CALL DIGWRITE'("AC1",0.0)
1730 CALL DIGWRITE'("AC4",0.0)
1740 REM MOTOR AND SOLENOID SHOULD NOW BE OFF AND FURNACE COOL
1750 RETURN:REM -----END ROUTINE TO COOL DOWN-----
1760 REM-----DISK SAVE ROUTINE FOLLOWS-----
1765 IF H$="n" THEN 1870
1770 'CALL ARGET'("HARRAY%", 1., nd!, 2, 1, E1, 12)
1780 'FOR I=1 TO 20:D=I
1790 'CALL ARGETVAL'("ARRAY%",D,2,VB,12)
1800 L$=TD$+"."+MID$(STR$(RN),2,3)+"int="+T$+"ms"+"mot.sp."+STR$(SP)
1810 'PRINT VB;" ";E1(I):NEXT I
1820 L1$="c:\s500\"+TD$+"."+MID$(STR$(RN),2,3)
1830 IF H$="n" THEN GOTO 1870
1831 IF H$="y" THEN L1$=L1$+"H"
1840 LOCATE 11,20:PRINT "Saving HEATUP Data as FILE ";L1$
1850 CALL ARLABEL'("ahRAY%",L$)
1860 CALL ARWRITE'("ahRAY%",L1$,12,1,5,1)
1870 L1$="":HU=0
1871 L$=TD$+"."+MID$(STR$(RN),2,3)+"int="+T$+"ms"+"mot.sp."+STR$(SP)
1872 L1$="c:\s500\"+TD$+"."+MID$(STR$(RN),2,3)
1874 LOCATE 12,20:PRINT "Saving QUENCH Data as FILE ";L1$
1875 CALL ARLABEL'("ARRAY%",L$)
1876 CALL ARWRITE'("ARRAY%",L1$,12,1,5,1)
1880 'TCDATA IS FILE NAME USED
1890 'ARRAY% IS A SOFT500 DATA ARRAY OF TEMPERATURES
1900 '12 IS ENGINEERING UNITS CONVERSION FOR S THERMOCOUPLE
1910 '4 IS TO SAVE DATA IN LOTUS FORMAT, 1 IS ASCII, 0 IS SOFT500, 2 & 3 ARE BINA
RY
1920 '5 IS TIME INTERVAL BETWEEN READINGS, HERE 5 MS
1930 '1 IS UNITS OF TIME INTERVAL OF ABOVE, HERE MS;2 IS SEC, 3 IS MIN
1940 'ARRAY NAME CANNOT BE USED AGAIN UNLESS IT IS ERASED:
1945 RETURN
1965 CLS:COLOR 20,,3
1970 LOCATE 5,20:PRINT "THE ARRAYS ARE BEING DELETED";
1980 CALL ARDEL'("ARRAY%")
1981 IF H$="n" THEN 1985
1982 CALL ARDEL'("AHRAY%")
1985 COLOR 3,,3
1990 RETURN
2000 REM -----READ DISK to verify data-----
2010 LOCATE 23,15:INPUT "Do you wish to REVIEW DATA from disk ? (y/n)";Y$
2020 IF Y$="Y" OR Y$="y" THEN 2030 ELSE 2080

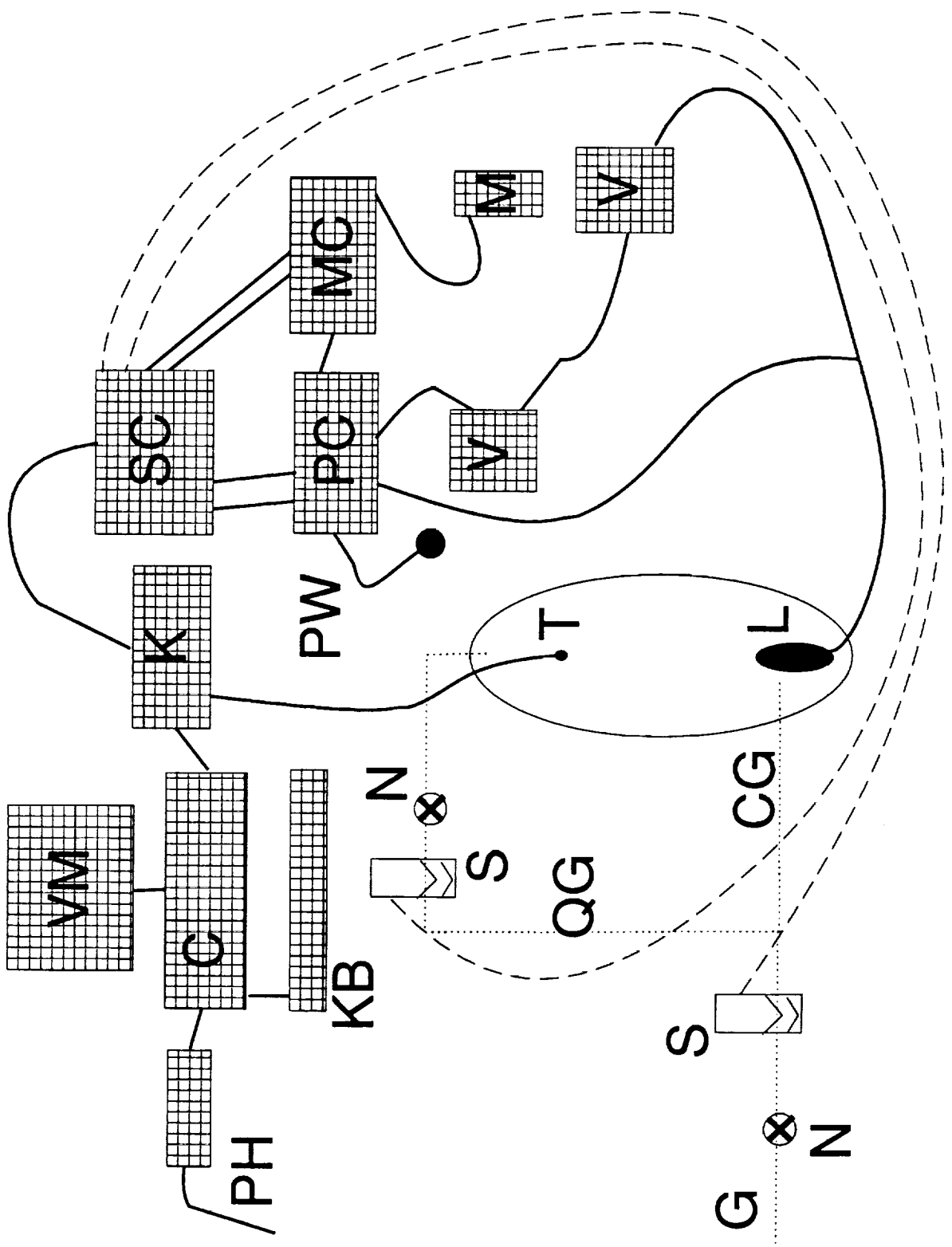
```

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2030 OPEN L1$ FOR INPUT AS #1
2040 FOR I=1 TO (ND+7)
2050 INPUT #1, Z:IF I<15 OR I>(ND-3) THEN PRINT I,Z
2060 NEXT I
2070 CLOSE #1
2080 RETURN:REM -----DISK OPERATIONS DONE-----
2290 '
2300 REM-----THIS IS THE REGRAPHING ROUTINE TO REVIEW DATA-----
2310 CLS
2320 SCREEN 1:REM NEED PROPER SCREEN FOR GRAPH, CHECK FOR CGA LEVEL &RES
2325 LOCATE 1,1:PRINT"1"
2326 LOCATE 2,1:PRINT"4"
2327 LOCATE 3,1:PRINT"0"
2328 LOCATE 4,1:PRINT"0"
2329 LOCATE 21,1:PRINT"0"
2330 'LINE (5,9)-(312,166),,B
2331 LINE (10,9)-(312,166),,B
2340 'LINE (5,9)-(312,84),,B
2341 LINE (10,9)-(312,84),,B
2365 IF H$="n" THEN 2372
2370 CALL GRAPH'("ahRAY%", "1 2", "1 2", "PAGEO", 00.0, 1400.0, "MAGNIFY", -1, 12)
2372 CALL GRAPH'("ARRAY%", "1 2", "1 2", "PAGEO", 00.0, 1400.0, "MAGNIFY", -1, 12)
2380 LOCATE 23,20:INPUT "Return to Continue";Y$
2390 SCREEN 2:SCREEN 0:WIDTH 80
2395 RETURN:REM-----END OF REGRAPHING ROUTINE-----

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Figure 1. Schematic of Telescience Testbed. PH phone/PABX, VM video monitor for computer, C IBM XT-type computer, KB keyboard for computer, K Keithly 500 Data Acquisition System outboard box, SC signal control center, PC power control center, PW power input, MC motor controller, M motor, V variac, T thermocouple, L lamp in ellipsoidal furnace, CG cooling gas for lamp, QG quench gas for specimen, S solenoid valve, G pressurized gas line, N flow adjustment valve. The Variac connected to the PC sets the maximum power available and is manually set. The Variac in series with the first one is adjusted by the motor both up and down. The signal control center determines the motor direction and operates it, the motor controller powers the motor and establishes the motor speed which is also manually set.



POWER TO EXPERIMENT TURNED ON

MSFC Telescience Rapid Thermal Analysis Test Bed
SSL-ES74 Testbed Laboratory Bldg 4481 Rm. 405C

```
Input Warmup Time =                ? 2
WAITING                                     2
How many Experiment Runs?           [1]  ? 1
What is MOTOR SPEED set to =       [3]  ? 2
Turn on GAS quench? (y or n)       [Y]  ? y
Furnace OFF for quench? (y or n)   [Y]  ? y
Maximum Soak Temperature =         [300] ? 300
Input Soak DURATION in seconds =    [1]  ?
NUMBER of Readings (10 to 1000)    [10] ? 200
FILE NAME for data =                [TCDATA] ?
INTERVAL between readings =         [50ms] ?
```

Temperature = 20 Deg C

Figure 2. Opening screen at Workstation with selected entries showing. Default values shown in square brackets. Unsuitable entries are rejected before proceeding. Temperature reading always showing which permits monitoring of system.

Figure 3. Second screen shows experiment status and elapsed time for each stage of run. Request for plots made here.

Run Number 1 of 1 Runs.
Motor and Solenoid ON for Heat Up Cycle

```
HEATUP Time          8.460938  sec
SOAK Time            5  sec
MAXIMUM soak Temp.   313  C
QUENCH Time (to 200C 155.98828125  sec
POST-QUENCH Time     2.19140625  sec
TOTAL process Time   171.640625  sec
```

DO you wish to REVIEW GRAPH y or n: ?

Temperature = 22 Deg CC

Do You Want a HIGH RESOLUTION graph (H)
OR ?
Do you want a LOW RESOLUTION graph (L)

THE ARRAYS ARE BEING DELETED
POWER to ALL equipment turned OFF
1 Runs Completed




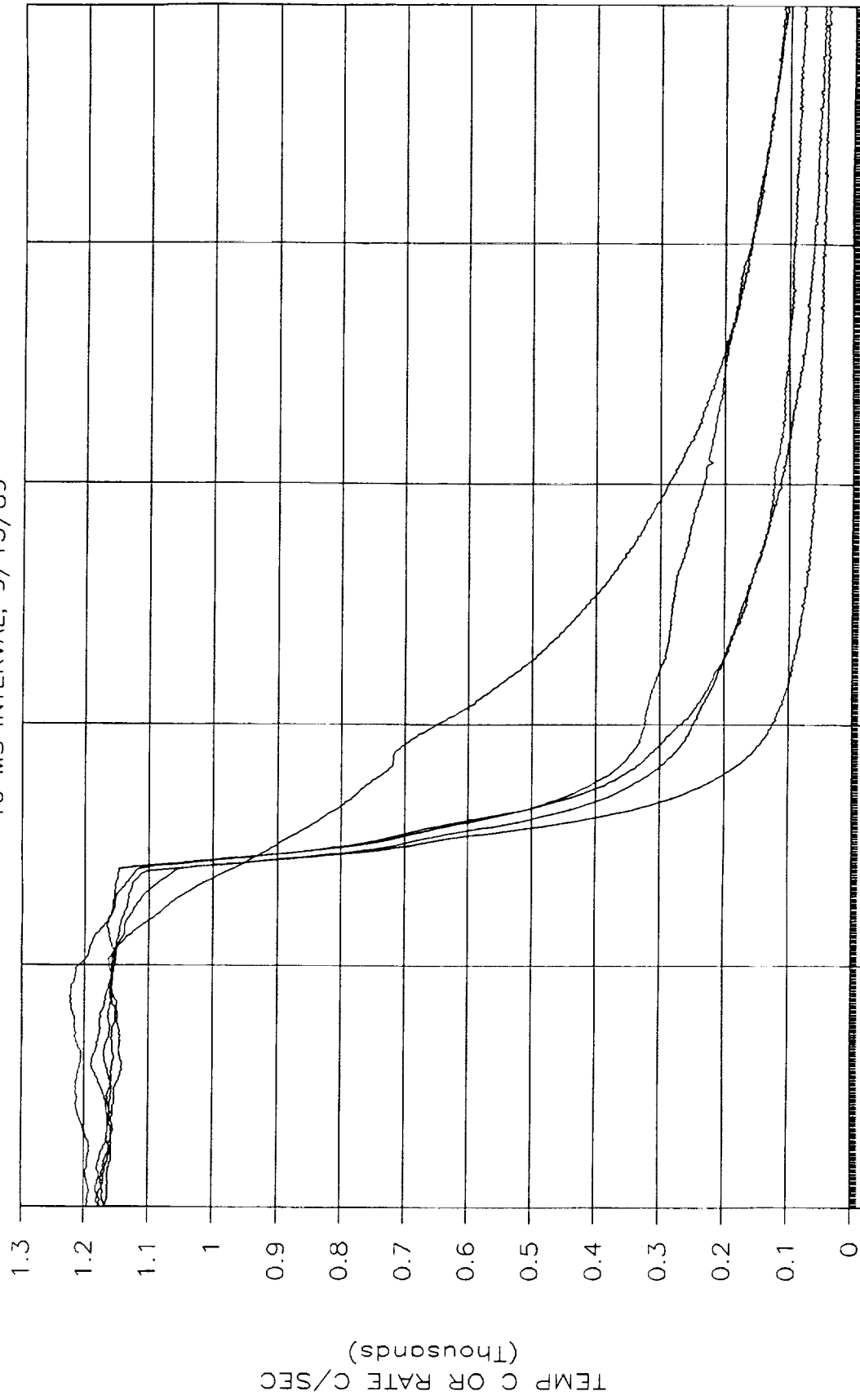
Figure 4. Two screens shown. First, a query screen for resolution of the plots. Second, the terminal screen at the end of the last run.

Figure 5. Test data plotted in highest resolution via Lotus 123. Post-experiment processing. This is original thermal data for a series of runs on the same specimen.

Figure 6. Test data processed and plotted via Lotus 123. Post-experiment processing. Here, derivatives of thermal data plotted to show cooling rates as a function of time.

TOP QUENCH COOLING RATE SERIES

10 MS INTERVAL, 9/13/89



INTERVAL 10 MS MARKED IN 100

TOP QUENCH COOLING RATE SERIES

10 MS INTERVAL, 9/13/89

